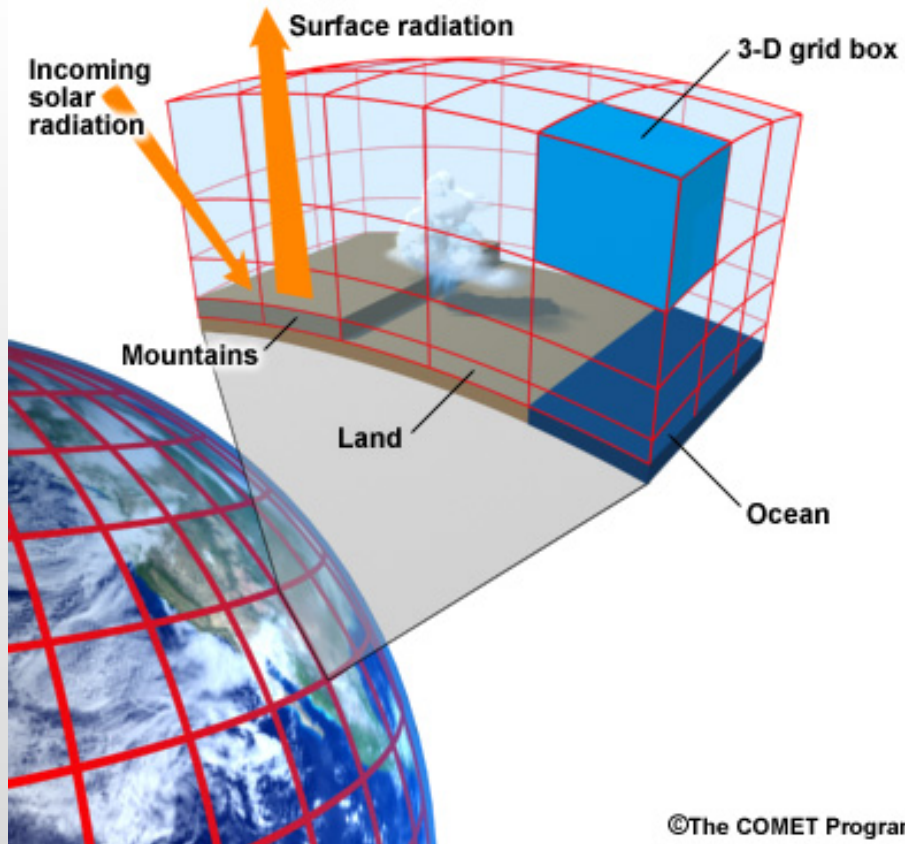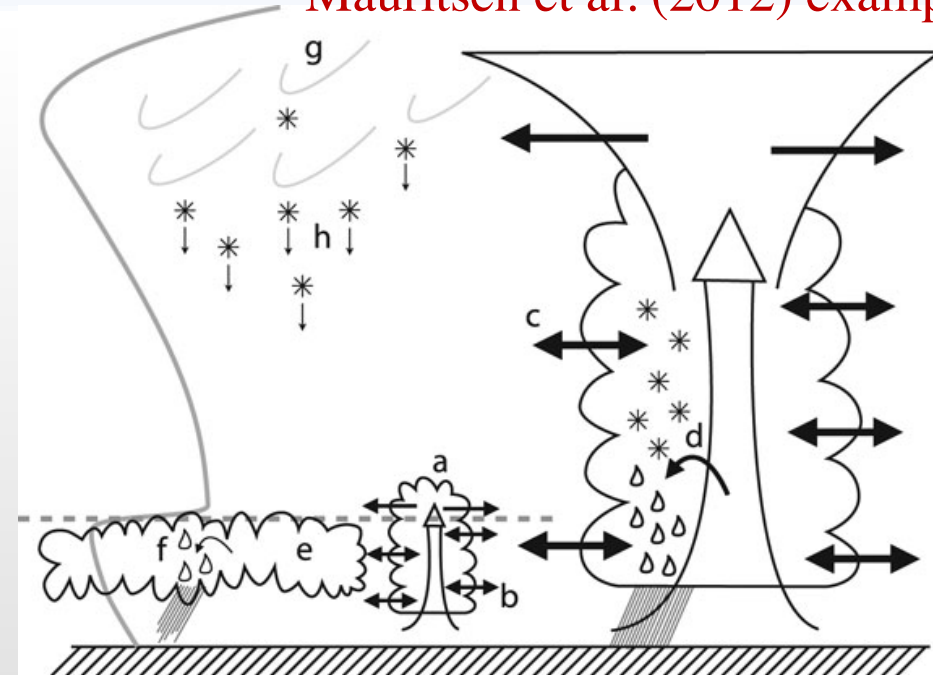# Plans for Determining the Optimal Combinations of Free Parameters to Tune the GISS-E3 GCM

Greg Elsaesser
(with anticipated many contributions from Marcus van Lier-Walqui, GISS GCM Clouds group, …)

Global Climate Model (GCM) Grid Boxes, Cloud Parameterizations, and Unknown (Free) Parameters

Mauritsen et al. (2012) example

a) mass flux (e.g. shallow clouds)
b & c) entrainment/detrainment rates
d & f) cloud water conversion to precipitation
e & g) cloud inhomogeneity
h) ice particle fall speed

Some Free Parameters specific to the GISS GCM…

Most-recent favorites, Prior to GISS-E3

U00a, U00b
[RH thresholds for cloud formation]

WMUI_multiplier, WMUL_multiplier
[autoconversion, cloud to precip]

radiusi_multiplier, radiusl_multiplier
[scale factor for ice/liq particle effective radii]

GISS-E3 (don't try to read, just note #)

Possible tuning parameters from cloud_sandbox (as of 08 MAY 2017):

(01) CCMUL, multiplier for convective cloud cover.
    Variation: 1 – 3 (multiplier, unitless).
(02) CCMUL2, multiplier for shallow anvil cloud cover.
    Variation: 1 – 5 (multiplier, unitless).
(03) TFMC, freezing point for MSTCNV ice condensation.
    Variation: (TFreezing-5) – (TFreezing-25) Kelvins.
(04) cloudrvl_mstcnv, volume-mean droplet radius for MSTCNV small-cloud-drop mode DSD.
    Variation: 5 – 15 um.
(05) cloudrvi_mstcnv, volume-mean ice particle rad for MSTCNV small-ice-particle-mode PSD.
    Variation: 5 – 15 um.
(06) entrainment_cont1, constant for plume 1 entrain rate.
    Variation: 0.10 – 0.40 (scaling factor).
(07) entrainment_cont2, constant for plume 2 entrain rate.
    Variation: 0.45 – 0.90 (scaling factor).
(08) RHCsl, reference critical RH for stable non-turbulent layers.
    Variation: 0.5 – 0.95 (fraction).
(09) RHCtl, reference critical RH for turbulent layers.
    Variation: 0.5 – 0.95 (fraction)
(10) MC_FDDRT, frac of plume ddraft condensate avail for evaporation.
    Variation: 0.25 – 1.0 (fraction, unitless).
(11) t_homf, homogeneous freezing temperature.
    Variation: (TFreezing-40) – (TFreezing-35) Kelvins.
(12) ni_homfree, in-cloud num conc of cloud ice nucleated.
    Variation: 75d3 – 250d3 (1/m3).
(13) dcs, threshold diameter for autoconversion of cloud ice to snow.
    Variation: 200d-6 – 600d-6 meters.
(14) pfrac_min, minimum weighting of cloud fraction by precip mass fraction.
    Variation: 0.2 – 0.8 (fraction).
(15) wb99_rh, RH appearing in Wilson and Ballard 1999 ice cloud formulation.
    Variation: 0.8 – 0.95 (fraction).
(16) ifluffy, cldice density scaling factor for effective radii.
    Variation: 0 – 1.0 (scaling factor).
(17) sfluffy, snow density scaling factors for effective radii.
    Variation: 0 – 1.0 (scaling factor).
(18) m_entrain_enhance, moist entrainment enhancement parameter from ATURB.f
    Variation: 15 – 40.0 (scaling factor).
(19) w_min, minimum updraft speed for CCN activation.
    Variation: 0.1 – 0.8 m/s.

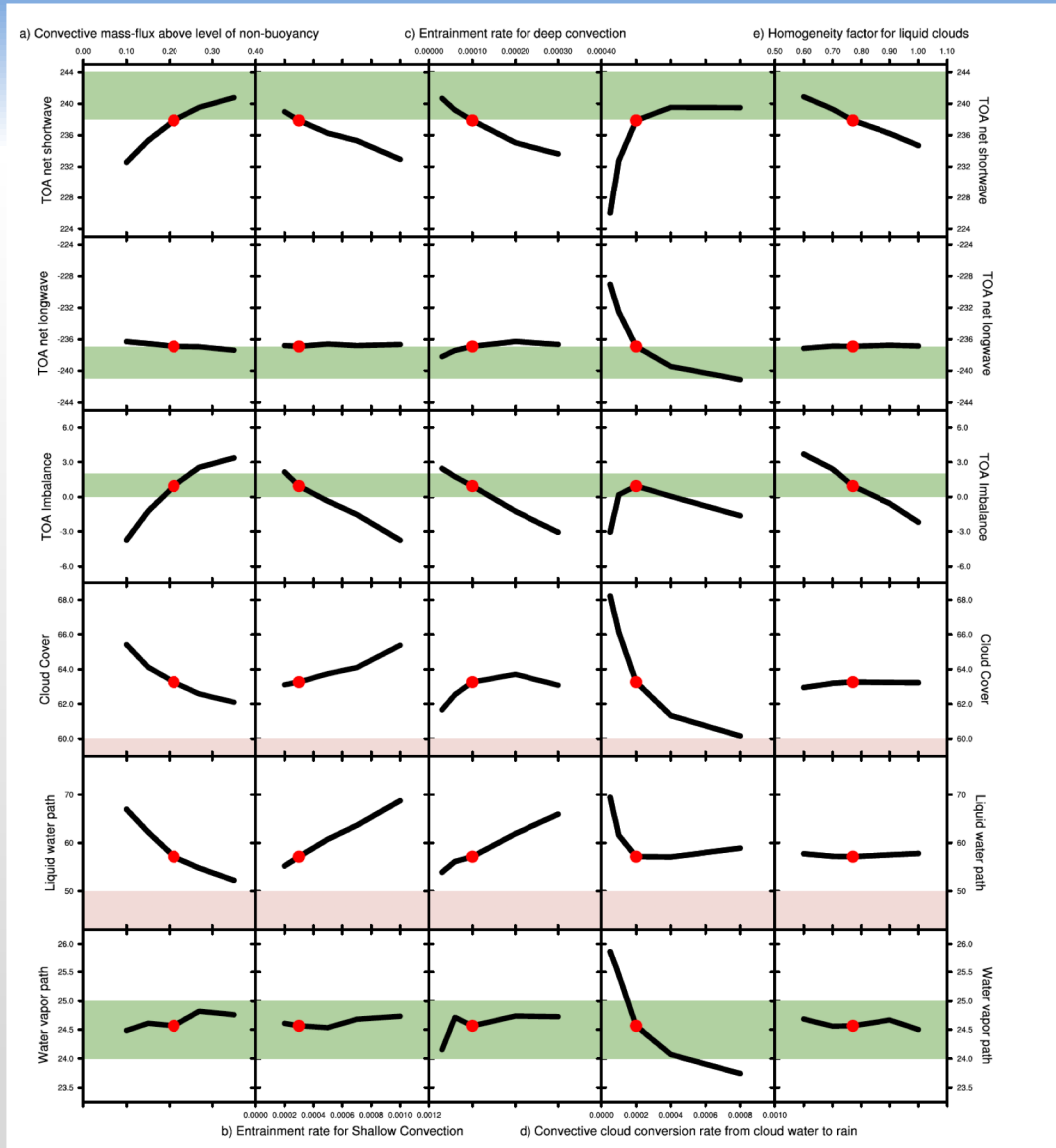# GCM Parameterization Free Parameter Tuning: Critical Step in Development

Mauritsen et al. 2012

Many unobserved processes and parameters, and many decisions to be made.

Key Points and Questions:
(Mauritsen et al. 2012; Hourdin et al. 2016; Schmidt et al. 2017, and many other recent pubs)

❖ Be transparent on how parameter combinations are decided upon.
❖ Do decisions on parameters today impact climate simulations of tomorrow?
❖ Multiple tuning strategies for a model. What is the role of observations?

GCM Parameterization Free Parameter Tuning: Critical Step in Development

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Towards clearly stating what groups do (Schmidt et al. 2017)

Table 2. Use of historical period trends and imbalances during the tuning process

| Modeling Group	Tuning Climate Sensitivity	Historical Temp. Trend	Radiative Balance (1850)	Radiative Imbalance (PD)	Aerosol Forcing
DOE	No	No	Yes	$>0.5 \text{W m}^{-2}$	Yes
GFDL	No	No	No	$<1.0 \text{W m}^{-2}$ [2]	Yes
GISS	No	No	Yes	No	Yes/No[1]
GMAO	No	No	N/A	No	No
NCAR	No	No	Yes	$0.5\text{--}1.0 \text{W m}^{-2}$	$<1.5 \text{W m}^{-2}$
NCEP	No	No	N/A	No	No

[1] Tuned in simulations with non-interactive composition only.
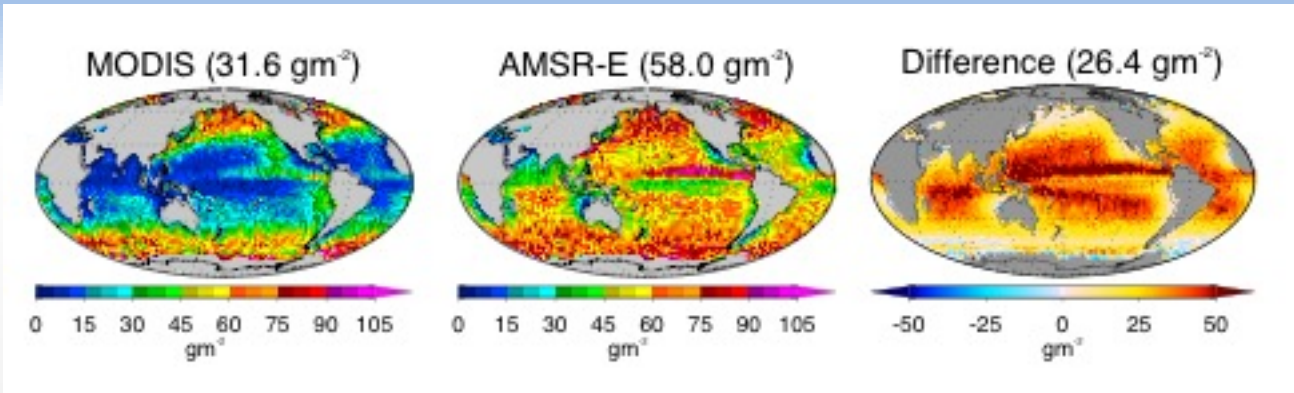[2] Using 1981–2000 AMIP simulations

GCM Parameterization Free Parameter Tuning: Observations critical, but what if they are biased?

Example of "observed" rainfall.

1 week after arriving at GISS, I finished a paper (Elsaesser et al. 2015) that showed how sensitive satellite retrievals of rainfall were to assumed errors (in simulated + obs radiances) in the official algorithm used in TRMM, SSM/I, etc. (known as GPROF). One of the SSM/I products is critical to GPCP.
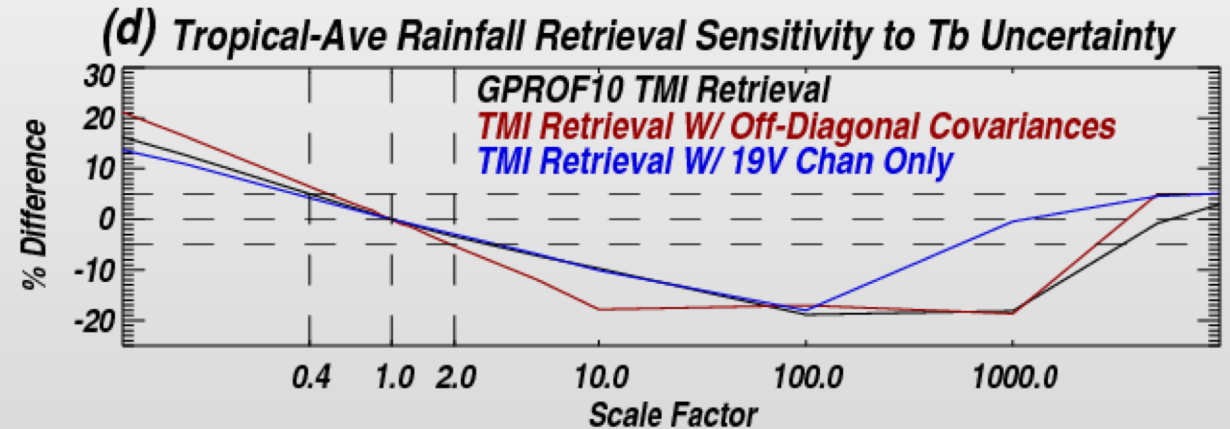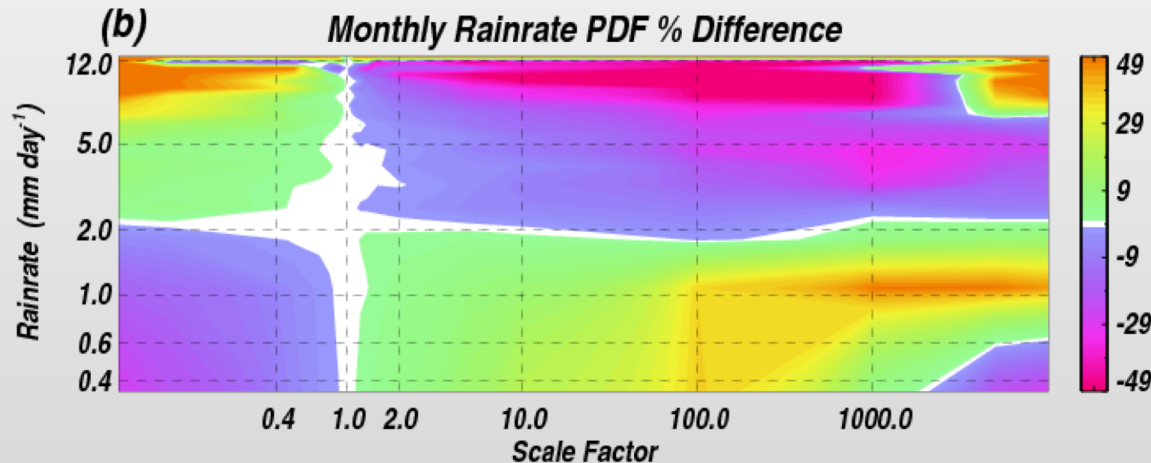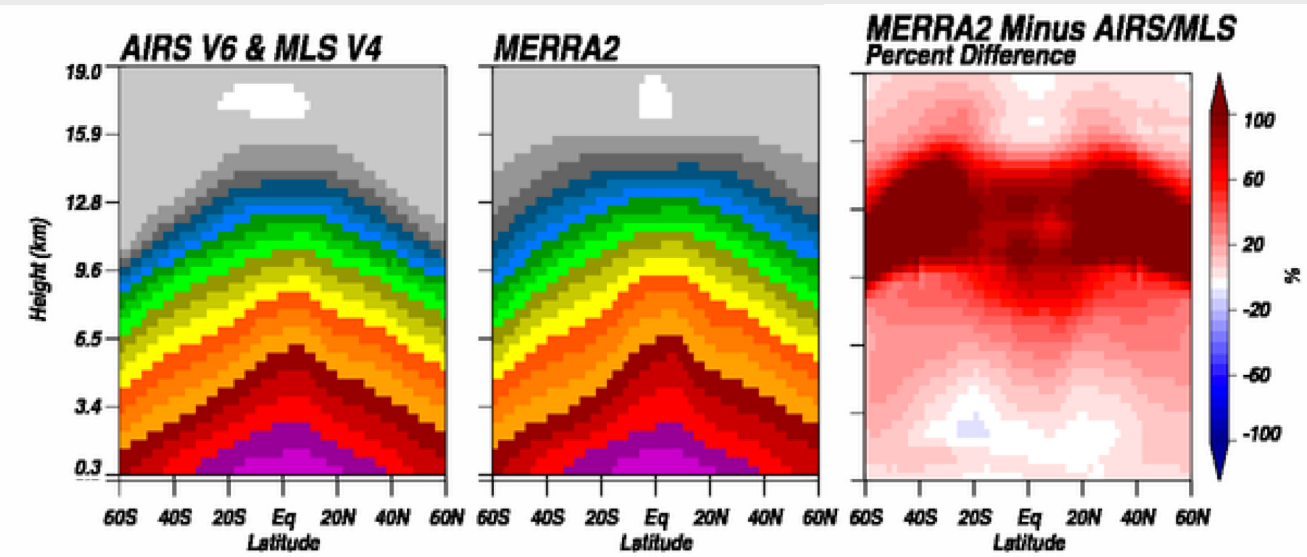
GCM Parameterization Free Parameter Tuning: Observations critical, maybe biased…and lack consensus?

MODIS (31.6 gm⁻²) AMSR-E (58.0 gm⁻²) Difference (26.4 gm⁻²)

Lebsock and Su (2014, JGR):
Lack of consensus in observations
of warm/shallow cloud liquid water path.

Obs4MIPS Archive: Water Vapor Profile Climatology
*AIRS V6 Obs4MIPS Early-Release Provided by Baijun Tian

AIRS V6 & MLS V4   MERRA2   MERRA2 Minus AIRS/MLS Percent Difference
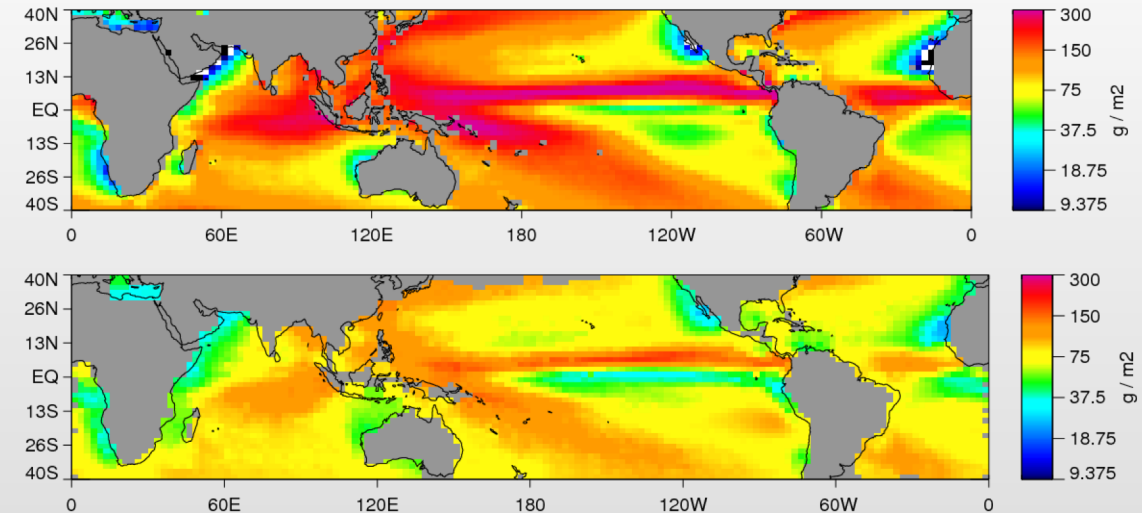
Total Liquid Water Path Climatology from
Elsaesser et al. (2017, JCLI) (Top) versus
TRMM 3A12 (Bottom)

GCM Parameterization Free Parameter Tuning: Observations critical, maybe biased…and lack consensus?
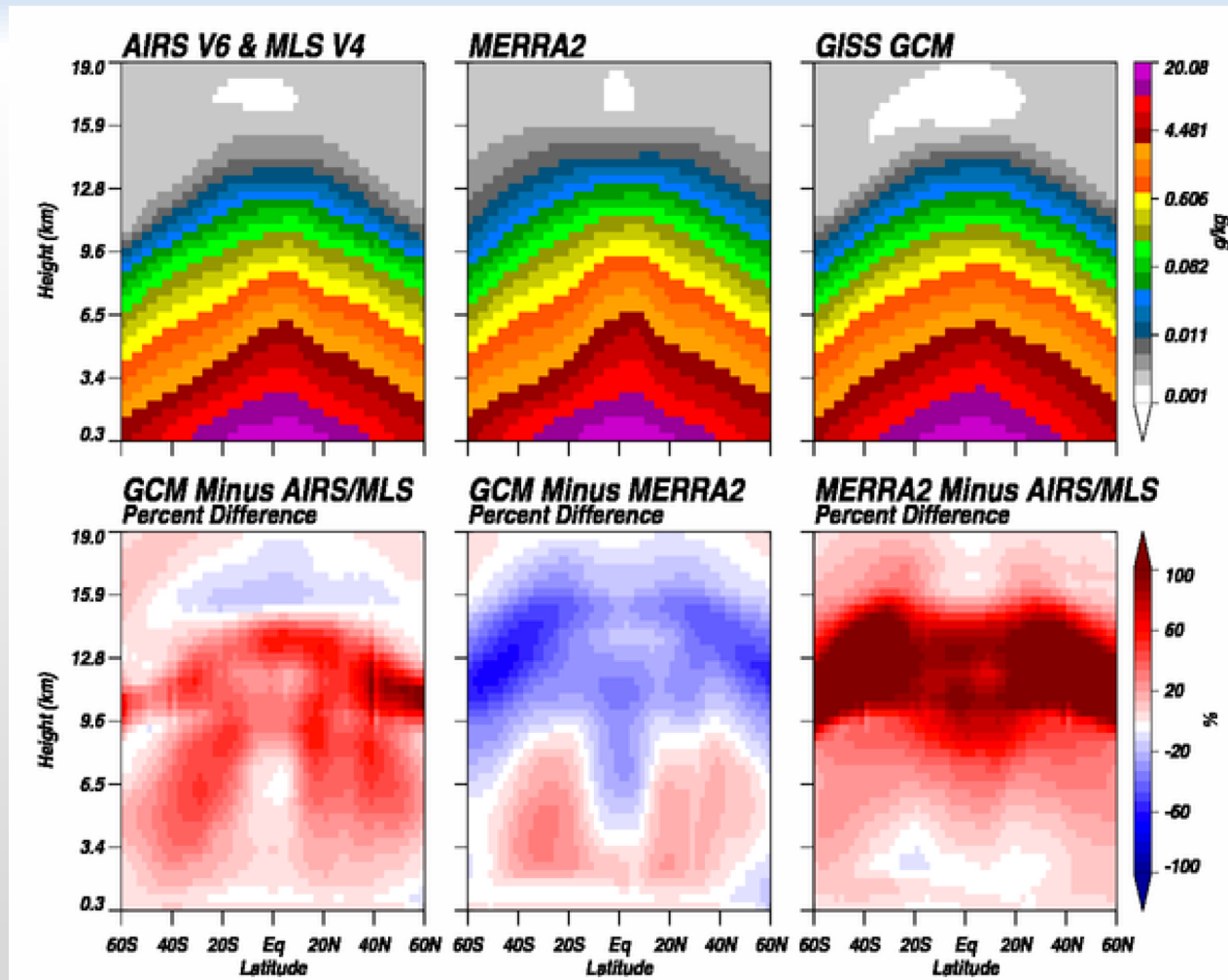
GISS GCM (ModelE3, in development): bias depends on which observations you use.

So, does it matter which product is the 'truth' reference for parameter settings?

Big-picture Q: Implications for future climate simulations?

GCM Parameterization Free Parameter Tuning:
Using one product versus multiple, and considering observational biases.

*Observational bias ≠ retrieval product uncertainty estimates.

$$E^2 = \frac{1}{W} \sum_i \sum_j \sum_t w_{i,j,t} (F_{i,j,t} - R_{i,j,t})^2$$

E is "model goodness" metric;
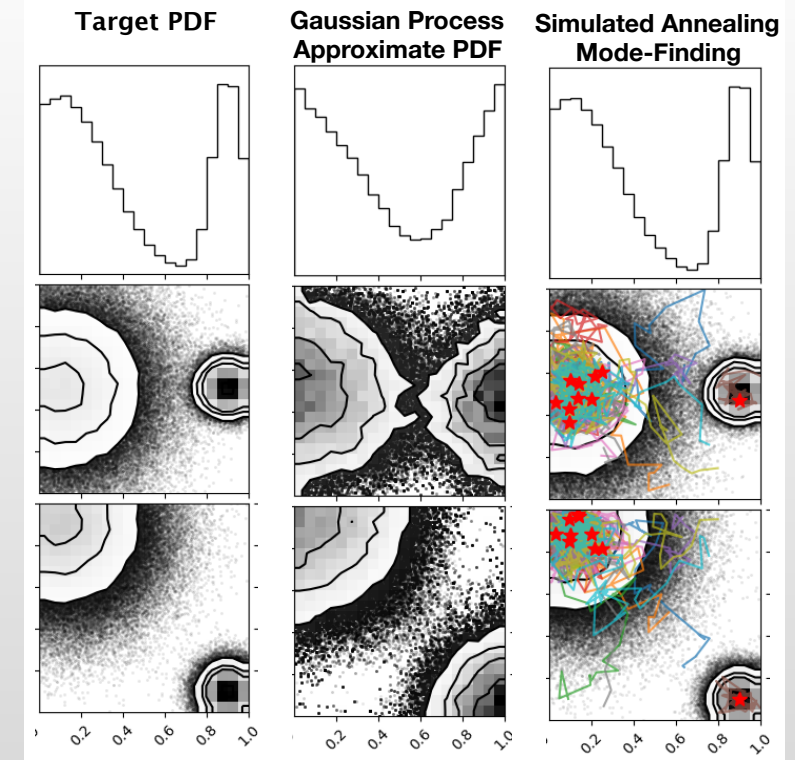F is the model field;
R is the reference/truth;
W is the weighting term.

Incorporate obs. bias into 'W'

(**i.e. key component of our work:**
develop a regime- or region-aware
**weighting; penalize model less where**
observational biases are larger)
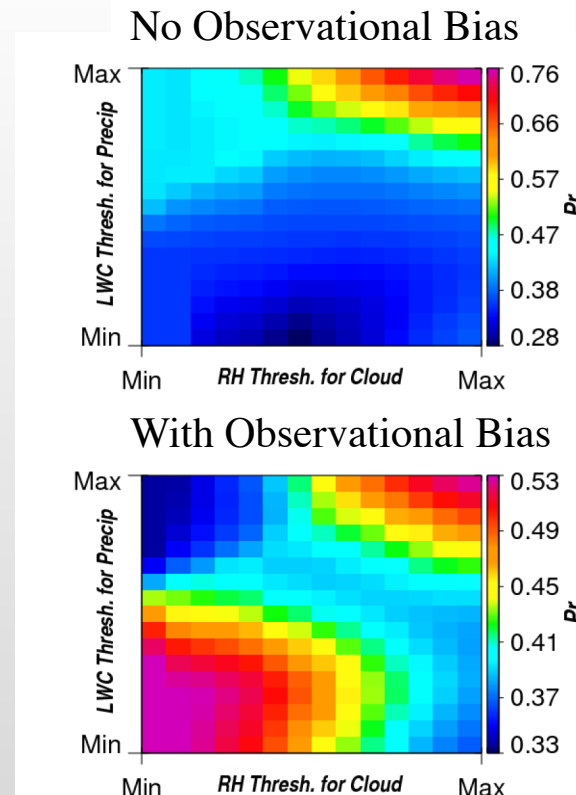
Use smart sampler to adjust parameters and find local maxima in goodness…

No Observational Bias

With Observational Bias

Target PDF   Gaussian Process Approximate PDF   Simulated Annealing Mode-Finding

GCM Parameterization Free Parameter Tuning:
## Using one product versus multiple, and considering observational biases.

Multi-dimensional state space in reality, with many combinations of parameters if observational bias is included in GCM goodness metric.
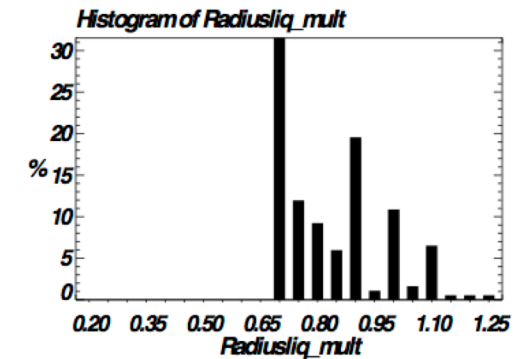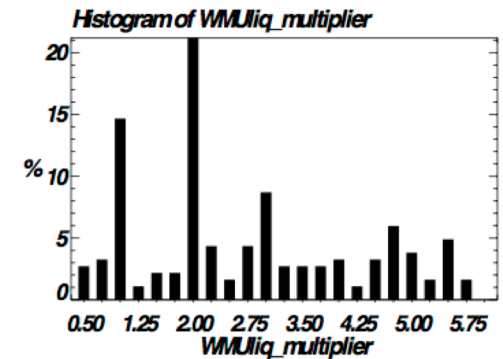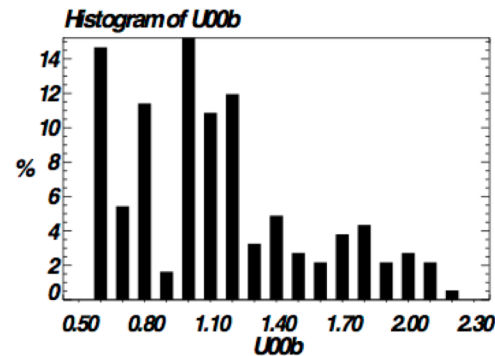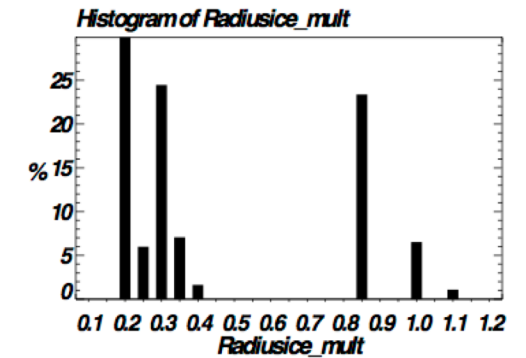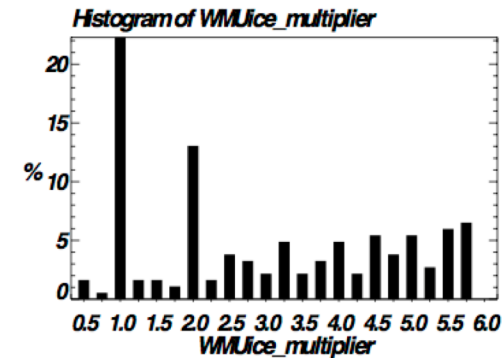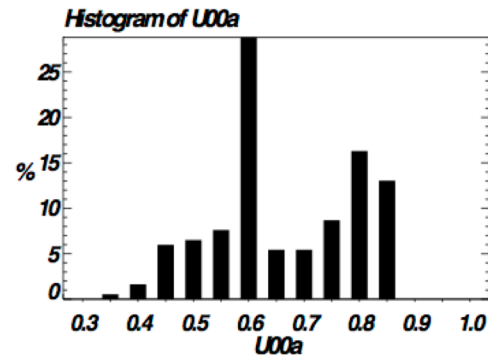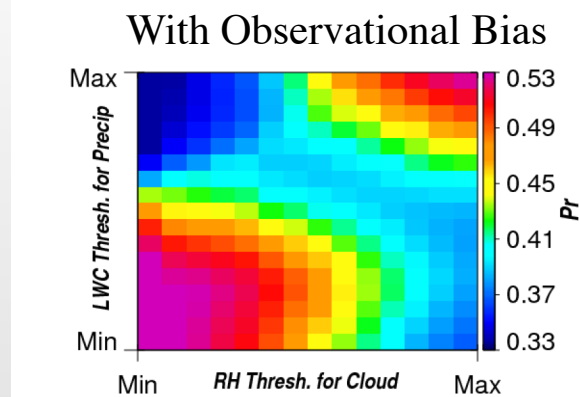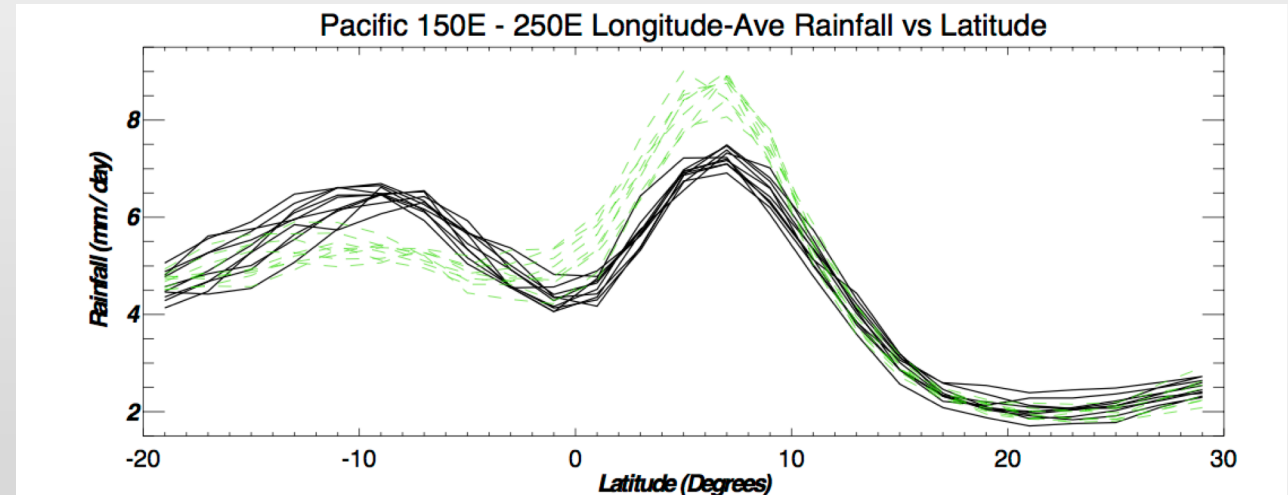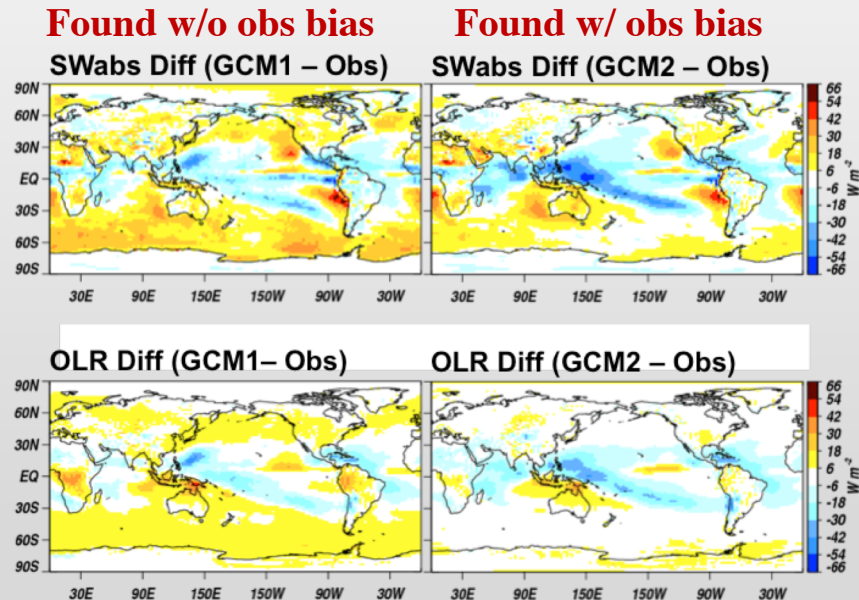
Impacts on Prescribed-SST GCM Experiments

Nearly Identical Taylor Diagram Scores;
color-shading denotes S. Oceans SWabs bias
($blue$-$green$-red denotes range from +20 to +5 W/m^2)

*few iterations after post-CMIP5
GISS GCM (left panels)
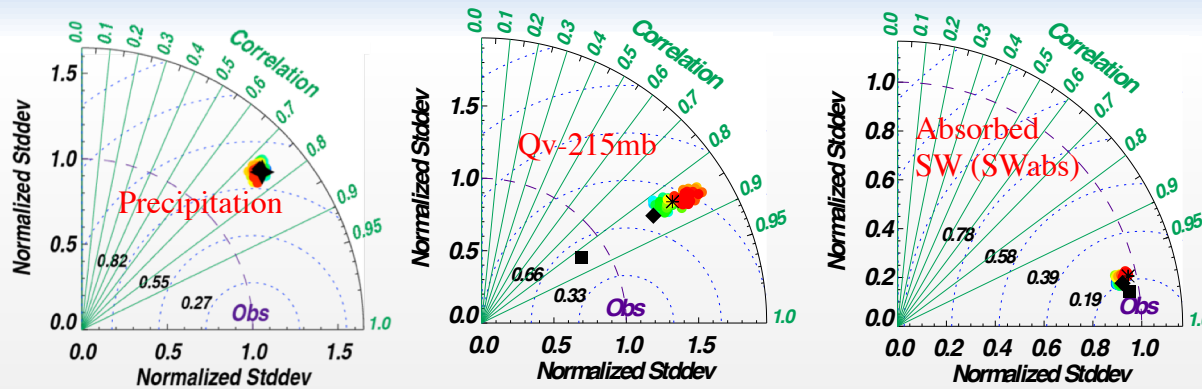
Wider range of admissable GCM configurations, with:

❖ traditional evaluation metrics (Taylor Diagrams) masking biases in radiation (left)

❖ Variations in the structure of the ITCZ/SPCZ precipitation features (below)

Found w/o obs bias   **Found w/ obs bias**

Pacific 150E - 250E Longitude-Ave Rainfall vs Latitude

- Observational bias is sometimes large, and often of greater magnitude than posted product uncertainty. Since most Earth system models have unknown parameters that need optimization (using observational products as references), each model's range of parameters may be expanded by taking into account such biases.

- Planning to use this approach for parameter optimization in GISS-E3, where "this approach" involves
  1. taking into account obs bias; 2. smart sampler (M. van Lier-Walqui)

- *Not* settling on one combination of parameters. How long do we need to do runs to get us into the neighborhoods of parameter space? How far beyond clouds parameter perturbations should we go?

Other ways to tune (i.e. to clusters, not maps)